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(54) **t-Butyl (R)-(-)-4-Cyano-3-hydroxybutyrate and process for its preparation**

T-Butyl-R-(-)-4-cyano-3-hydroxybutyrat und Verfahren zu seiner Herstellung

T-butyl-R-(-)-4-cyano-3-hydroxybutyrate et procédé de sa préparation

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(56) References cited:
DE-A- 1 547 969

• **TETRAHEDRON LETTERS vol. 33, no. 17, 21 April**
1992, pages 2279 - 2282 P.L. BROWER ET AL

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Description

This invention relates to t-butyl (R)-(-)-4-cyano-3-hydroxybutyrate which is useful as an intermediate of a variety of medicines. For example, this compound can be the precursor of 4-hydroxy-3,4,5,6-tetrahydro-2H-pyran-2-one, a lactone moiety which seems to be an active site of 3-hydroxy-3-methylglutaryl coenzyme A (hereinafter abbreviated as HMG-CoA) reductase inhibitors.

(R)-(-)-4-Cyano-3-hydroxybutyric acid esters are known to be easily converted to the active lactone site of Compactin, Mevalotin and Pravastatin, which are considered to be useful as a cholesterol depressant or an HMG-CoA reductase inhibitor. For example, it is reported that an (R)-4-cyano-3-hydroxybutyric acid ester with its hydroxyl group protected with a trialkylsilyl group or a tetrahydropyranyl group is hydrolyzed to form an amide which is then treated with an acid to obtain (R)-4-hydroxy-3,4,5,6-tetrahydro-2H-pyran-2-one, as disclosed in U.S. Patent 4,611,067.

It is also reported that an HMG-CoA reductase inhibitor containing a phosphorus atom in the molecule thereof is obtained by halogen exchange of methyl (S)-4-bromo-3-hydroxybutyrate prepared from isoascorbic acid with its hydroxyl group protected to obtain a corresponding iodide compound, which is then converted to a Wittig-Hornor reagent, followed by several additional steps, as disclosed in J. Med. Chem., Vol. 33, p. 2952 (1990).

EP 0 330 172 A discloses that a 4-cyano-3-hydroxybutyric acid derivative with its hydroxyl group protected is reacted with a malonic acid derivative to obtain a 6-cyano-3-oxohexanoic acid derivative, which is further led to a cholesterol biosynthesis inhibitor.

Known processes for synthesizing optically active 4-cyano-3-hydroxybutyric esters include a process comprising leading arabinose or ascorbic acid as an asymmetric source to methyl (S)-4-bromo-3-hydroxybutyrate according to the technique described in Acta Chem. Scand., Vol. B37, p. 341 (1983) and, after protecting the hydroxyl group with a tetrahydropyranyl group, a trialkylsilyl group, an alkyl group, etc., reacting the protected compound with sodium cyanide according to the technique as disclosed in U.S. Patent 4,611,067 and a process comprising reacting L-ascorbic acid with hydrogen peroxide and calcium carbonate to form calcium L-threonate monohydrate and reacting the compound with hydrogen bromide to obtain a dibrominated compound, which is then led to a bromohydrin compound according to the process disclosed in Carbohydrate Res., Vol. 72, p. 301 (1979), followed by the above-mentioned protection of the hydroxyl group and reaction with sodium cyanide.

Preparation of ethyl 4-cyano-3-hydroxybutyrate is reported in Bull. Soc. Chim. Fr., (4) 33 (1923), 732, which comprises hydrolyzing 4-chloro-3-hydroxybutyronitrile to obtain a carboxylic acid, converting the carboxylic acid into its ethyl ester, and reacting the ethyl ester with potassium cyanide. However, the yield reported is low, and the literature makes no mention of optical activity.

The activity of the HMG-CoA reductase inhibitors is known to owe much to the steric configuration(s) of the hydroxyl group of the lactone moiety or of the two hydroxyl groups of the precursor β,δ -dihydroxycarboxylic acid.

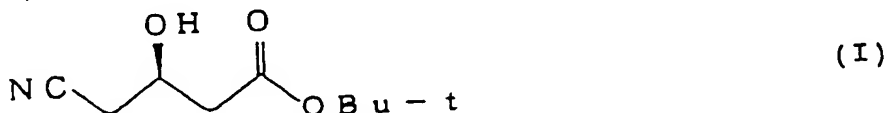
For example, reduction in inhibitory activity depending on the steric configuration of the hydroxyl group is mentioned e.g., in J. Med. Chem., Vol. 30, p. 1858 (1987) and J. Org. Chem., Vol. 51, p. 4931 (1986). That is, it is required to have high activity that the steric configuration of the hydroxyl groups at the β - and δ -positions of β,δ -dihydroxycarboxylic acid forms a *cis*-configuration.

EP 0 024 348 A and U.S. Patents 4,611,068 and 4,855,481 describe that the 4-hydroxyl group of the lactone ring of Compactin or Mevinolin must have an (*R*)-configuration to manifest the inhibitory activity and that conventional synthesis not only involves separation of the desired optically active compound which is accompanied with formation of an undesired isomer but also requires a very long reaction route.

In view of these reports made to date, the conventional processes have required protection of a hydroxyl group or separation of an optically active compound and involved many steps for obtaining a lactone ring moiety having high inhibitory activity. It has therefore been desirable to develop an economical synthetic process which has a short reaction route and is easy to carry out.

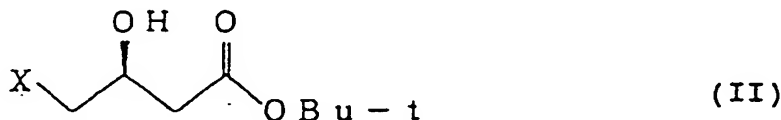
As a result of extensive investigations, the present inventors have found that t-butyl (R)-(-)-4-cyano-3-hydroxybutyrate, useful as an intermediate of medicines, can be obtained with ease by cyanogenation of a t-butyl (S)-(-)-4-halogeno-3-hydroxybutyrate which is easily obtained by enantioselective hydrogenation of a t-butyl 4-halogenoacetoacetate obtainable from diketene. The present invention has been completed based on this finding.

The present invention relates to t-butyl (R)-(-)-4-cyano-3-hydroxybutyrate represented by formula (I):



wherein Bu-t represents a t-butyl group.

The present invention also relates to a process for preparing the said t-butyl (R)-(-)-4-cyano-3-hydroxybutyrate (I) comprising reacting a t-butyl (S)-(-)-4-halogeno-3-hydroxybutyrate represented by formula (II):



wherein Bu-t is as defined above and X represents a chlorine atom or a bromine atom, with a cyanide represented by formula (III):



wherein M represents a sodium atom or a potassium atom.

The starting compound, a t-butyl 4-halogenoacetoacetate, is easily obtainable from diketene according to known processes disclosed, e.g., in JP-A-61-146191 (the term "JP-A" as used herein means an unexamined published Japanese patent application)

The optically active starting compound, a t-butyl (S)-(-)-4-halogeno-3-hydroxybutyrate, can be obtained by enantioselective hydrogenation of a t-butyl 4-halogenoacetoacetate in the presence of a ruthenium-optically active phosphine complex, e.g., $\text{Ru}_2\text{Cl}_4(\text{BINAP})_2(\text{C}_2\text{H}_5)_3\text{N}$ (wherein BINAP represents 2,2'-bis(diphenylphosphino)-1,1'-binaphthyl), according to the process described in U.S. Patent 4,895,979. In this reaction, use of (R)-(+)-BINAP as a ligand of the ruthenium-optically active phosphine complex gives a desired (S)-compound. The optically active t-butyl (S)-(-)-4-halogeno-3-hydroxybutyrate may also be obtained from microorganism fermentation of a t-butyl 4-halogenoacetoacetate as described in JP-A-61-146191.

The cyanogenation can be carried out by dissolving a t-butyl (S)-(-)-4-halogeno-3-hydroxybutyrate of formula (II) in an aprotic polar solvent, such as dimethylformamide, acetonitrile or dimethyl sulfoxide, adding an aqueous solution of a cyanide of formula (III) thereto, and stirring the mixture at a temperature in the range of from 15 to 100°C, and preferably from 40 to 70°C, for a period of from 2 to 5 hours, and preferably from 2 to 3 hours. The resulting reaction mixture is extracted with an organic solvent, e.g., ethyl acetate, toluene, diisopropyl ether or methylene chloride, the extract is washed with water, the solvent is removed by distillation, and the residue is recrystallized, e.g. from toluene, ethyl acetate, ethyl alcohol or isopropyl alcohol, to give a compound of the formula (I).

One of the advantages provided by the present invention is a high optical purity of the compound of formula (I). While there is no easy means available for increasing the optical purity of other lower alkyl esters (e.g., the ethyl, propyl or n-butyl ester) due to their liquid character, the compound of formula (I), being a crystal, can be obtained with an increased optical purity by recrystallization which cannot be applied to the other esters. This is a novel feature of the present invention.

Another advantage of the present invention resides in that the compound of formula (I) is less susceptible to saponification during cyanogenation than the other esters and therefore suffers from no great reduction in yield as encountered with the other esters.

The present invention will now be illustrated in greater detail with reference to illustrative Examples and Comparative Examples. The percentages are by weight.

Analyses of the compounds prepared were made with the instruments described below.

¹H-NMR:

AMX-400 (400 MHz) (manufactured by Bruker, Inc.)

Internal standard:

tetramethylsilane

Optical Rotation:

DIP-360 (manufactured by JASCO Inc.)

Optical Purity and Chemical Purity:

High performance liquid chromatograph L-6000 (manufactured by Hitachi, Ltd)

Detector: UV detector L-4000 UV (manufactured by Hitachi, Ltd.)

IR Spectrum:

IR-810 (manufactured by JASCO Inc.)

Melting Point:

Micro melting point apparatus (manufactured by Yanagimoto Seisakusho K.K.)

The optical purity was obtained in terms of enantiomer excess (e.e.), which, in cases where a concentration of an (*R*)-compound [*R*] is greater than that of an (*S*)-compound [*S*], is calculated according to equation:

$$\%ee = \{([R] - [S]) / ([R] + [S])\} \times 100$$

EXAMPLE 1

1) Preparation of t-Butyl (*S*)-(-)-4-Chloro-3-hydroxybutyrate:

In a 100 ml Hastelloy-made autoclave having been purged with nitrogen were charged 58.35 g (0.3 mol) of t-butyl 4-chloroacetoacetate and 120 ml of t-butyl alcohol, and solution of 250 mg (0.00015 mol) of $Ru_2Cl_4[(R)-(+)-BINAP]_2Et_3N$ in 2 ml of methylene chloride was added thereto. The mixture was stirred at 100°C under a hydrogen pressure of 10 to 15 kg/cm² for 2 hours to conduct hydrogenation. The solvent was evaporated, and the residue was distilled under reduced pressure to give 53.0 g (percent yield: 90%) of t-butyl (*S*)-(-)-4-chloro-3-hydroxybutyrate as a colorless clear liquid.

The absolute configuration was determined by comparing with a known product.

Optical purity: 92%ee
Boiling Point: 113-116°C/2 mmHg
 $[\alpha]_D^{25} = -94.7^\circ$ (c=1.88, methanol)
IR (neat) ν_{max} (cm⁻¹): 3450, 2950, 1730, 1630
¹H-NMR δ (ppm): 1.47 (9H, s), 2.55 (4H, m), 3.42 (1H, br s), 3.58 (2H, m), 4.22 (1H, m)

2) Preparation of t-Butyl (*R*)-(-)-4-Cyano-3-hydroxybutyrate:

In 120 ml of dimethyl sulfoxide was dissolved 36.7 g (0.22 mol) of the compound obtained in (1) above, and 45 ml of an aqueous solution containing 12.7 g (0.25 mol) of sodium cyanide was added thereto, followed by stirring at 65°C for 3 hours to give a conversion of 100%. The reaction mixture was extracted with 120 ml of ethyl acetate. The organic layer was washed with water and dried over anhydrous magnesium sulfate. The solvent was evaporated, and the residue was distilled to give 22.6 g (percent yield: 65%) of crude t-butyl (*R*)-(-)-4-cyano-3-hydroxybutyrate.

Optical Purity: 92%ee
Boiling Point: 130-135°C/0.2mmHg

Recrystallization of the crude product from 80 ml of toluene affgare 15.8 g of - t-butyl (*R*)-(-)-4-cyano-3-hydroxybutyrate in a percent yield of 70% based on the crude product.

Optical Purity: 99%ee or more
Melting Point: 63-64°C
 $[\alpha]_D^{25} = 2.09^\circ$ (c=1.05, methanol)
IR (KBr) ν_{max} (cm⁻¹): 3450, 2950, 2260, 1730, 1630, 1190
¹H-NMR (CDCl₃) δ (ppm): 1.46 (9H, s), 2.55 (2H, m), 3.45 (1H, br s), 3.59 (2H, dd, J=1.2, 5.6Hz), 4.21 (1H, m)

COMPARATIVE EXAMPLE 1

Preparation of n-Butyl (*R*)-(-)-4-Cyano-3-hydroxybutyrate

In a 100 ml Hastelloy-made autoclave having been purged with nitrogen were charged 38.8 g (0.2 mol) of n-butyl 4-chloroacetoacetate and 50 ml of n-butyl alcohol, and solution of 73 mg of $Ru_2Cl_2[(R)-(+)-BINAP]_2Et_3N$ in 2 ml of methylene chloride was added thereto. The mixture was stirred at 100°C under a hydrogen pressure of 11 to 12 kg/cm² for 2 hours to conduct hydrogenation. The solvent was evaporated, and the residue was distilled under reduced pressure to give 35.0 g (percent yield: 90%) of n-butyl (*S*)-(-)-4-chloro-3-hydroxybutyrate.

Optical purity: 94%ee
Boiling Point: 118-120°C/2mmHg
 $[\alpha]_D^{25} = -14.1^\circ$ (c=1, chloroform)
IR (neat) ν_{max} (cm⁻¹): 3450, 2950, 1730, 1630

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¹H-NMR δ (ppm): 0.94 (3H, t, J=7.3Hz), 1.39 (2H, m), 1.62 (2H, m), 2.63 (4H, m), 4.14 (2H, t, J=6.7Hz), 4.35 (1H, m)

The resulting compound was cyanogenated in the same manner as in Example 1-(2). That is, 58.5 g (0.3 mol) of n-butyl (S)-(-)-4-chloro-3-hydroxybutyrate was dissolved in 180 ml of dimethyl sulfoxide, and 67.5 ml of an aqueous solution containing 16.7 g (0.34 mol) of sodium cyanide was added thereto, followed by stirring at 65°C for 2 hours. The reaction mixture was worked up in the same manner as in Example 1-(2) to obtain n-butyl (R)-(-)-4-cyano-3-hydroxybutyrate in a percent yield of 58%.

Optical Purity: 94%ee
Boiling Point: 125°C/0.5mmHg
[α]_D²⁵ = -23.5° (c=1.48, chloroform)
IR (neat)ν_{max} (cm⁻¹): 3450, 2950, 2260, 1730, 1630, 1190
¹H-NMR (CDCl₃) δ (ppm): 0.94 (3H, t, J=7.3Hz), 1.39 (2H, m), 1.62 (2H, m), 2.63 (4H, m), 4.14 (2H, t, J=6.7Hz), 4.35 (1H, m)

COMPARATIVE EXAMPLE 2

Preparation of Ethyl (R)-(-)-4-Cyano-3-hydroxybutyrate

In 120 ml of dimethyl sulfoxide was dissolved 36.7 g (0.22 mol) of ethyl (S)-(-)-4-chloro-3-hydroxybutyrate which had been obtained in the same manner as in Example 1 and Comparative Example 1, and 45 ml of an aqueous solution containing 12.7 g (0.25 mol) of sodium cyanide was added thereto. The mixture was stirred at 65°C for 2 hours to complete the reaction. The conversion attained was 90%.

The reaction mixture was extracted with 120 ml of ethyl acetate, and the organic layer was washed with 400 ml of water and dried over anhydrous magnesium sulfate. The aqueous layer was extracted twice with 60 ml portions of ethyl acetate. The combined organic layers were dried, the solvent was removed by distillation, and the residue was distilled to furnish 20 g (percent yield: 57.5%) of ethyl (R)-(-)-4-cyano-3-hydroxybutyrate.

Optical Purity: 95.6%ee
Boiling Point: 115°C/2mmHg
[α]_D²⁰ = -27.0° (c=1.1, chloroform)
IR (neat)ν_{max} (cm⁻¹): 3450, 2970, 2260, 1730, 1630
¹H-NMR (CDCl₃) δ (ppm): 1.29 (3H, t, J=7.2Hz), 2.63 (4H, br s), 3.42 (1H, br s), 4.20 (2H, q, J=7.2Hz), 4.34 (1H, m)

COMPARATIVE EXAMPLE 3

Preparation of Propyl (R)-(-)-4-Cyano-3-hydroxybutyrate

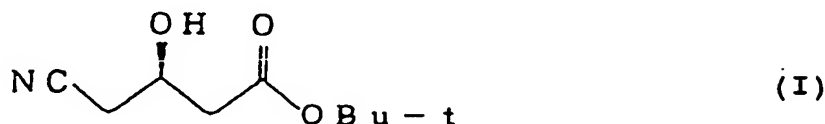
In the same manner as in Comparative Example 2, propyl (R)-(-)-4-cyano-3-hydroxybutyrate was obtained from propyl (S)-(-)-4-chloro-3-hydroxybutyrate in a percent yield of 56.5% with an optical purity of 95%ee.

Boiling Point: 110°C/0.3mmHg
[α]_D²⁵ = -23.6° (c=1.1, chloroform)
IR (neat)ν_{max} (cm⁻¹): 3450, 2950, 2260, 1730, 1630, 1190
¹H-NMR (CDCl₃) δ (ppm): 0.96 (3H, t, J=7.2Hz), 1.68 (2H, d, d, q, J=0.2, 6.7, 7.4Hz), 2.62 (4H, m), 4.10 (2H, t, J=6.7Hz), 4.34 (1H, m)

According to the present invention, t-butyl (R)-(-)-4-cyano-3-hydroxybutyrate can be obtained with high optical purity by cyanogenation of a t-butyl (S)-(-)-4-halogeno-3-hydroxybutyrate which can be obtained by enantioselective hydrogenation of a t-butyl 4-halogenoacetoacetate easily obtainable from diketene. The present invention makes it feasible to prepare optically active t-butyl 4-cyano-3-hydroxybutyrate with an economic advantage on an industrial scale.

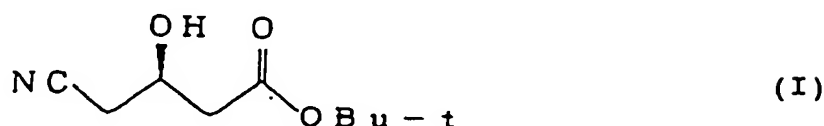
Claims

1. t-Butyl (*R*)-(-)-4-cyano-3-hydroxybutyrate represented by formula (I):

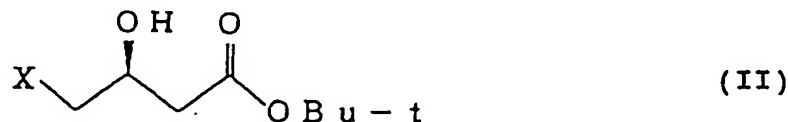


wherein Bu-t represents a t-butyl group.

- 15 2. A process for preparing t-butyl (*R*)-(-)-4-cyano-3-hydroxybutyrate represented by formula (I):



25 wherein Bu-t represents a t-butyl group, comprising reacting a t-butyl (*S*)-(-)-4-halogeno-3-hydroxybutyrate represented by formula (II):

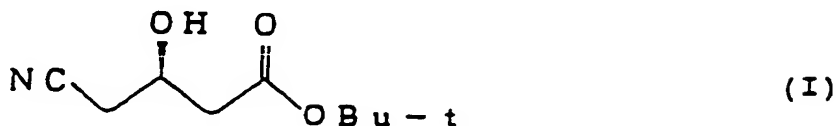


35 wherein Bu-t is as defined above; and X represents a chlorine atom or a bromine atom, with sodium cyanide or potassium cyanide.

- 40 3. A process as in Claim 2, wherein the reaction temperature is in the range of 15 to 100°C and the reaction period is from 2 to 5 hours.
4. A process as in Claim 3, wherein the reaction temperature is from 40 to 70°C and the reaction period is from 2 to 3 hours.
- 45 5. A process as in Claim 2, 3 or 4, wherein the t-butyl (*S*)-(-)-4-halogeno-3-hydroxybutyrate represented by formula (II) is dissolved in an aprotic polar solvent before the reaction with the cyanide.
6. A process as in Claim 5, wherein the aprotic polar solvent is dimethylformamide, acetonitrile or dimethyl sulfoxide.
- 50 7. A process as in any of claims 2 to 6, wherein the cyanide is present in the form of an aqueous solution.

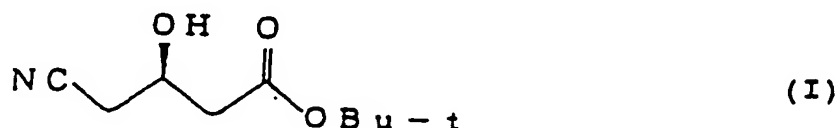
Patentansprüche

1. t-Butyl(R)-(-)-4-cyano-3-hydroxybutyrat, dargestellt durch die Formel (I):

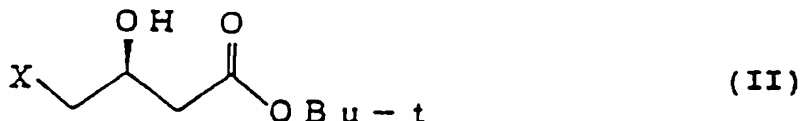


worin Bu-t eine t-Butylgruppe bedeutet.

2. Verfahren zum Herstellen von t-Butyl(R)-(-)-4-cyano-3-hydroxybutyrat, dargestellt durch die Formel (I):



worin Bu-t eine t-Butylgruppe bedeutet, umfassend das Reagierenlassen eines t-Butyl(S)-(-)-4-halogen-3-hydroxybutyrats, dargestellt durch die Formel (II):

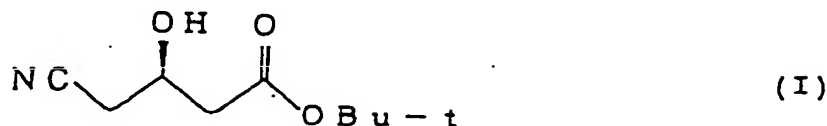


worin Bu-t wie vorstehend definiert ist; und X ein Chloratom oder ein Bromatom bedeutet, mit Natriumcyanid oder Kaliumcyanid.

3. Verfahren nach Anspruch 2, worin die Reaktionstemperatur im Bereich von 15 bis 100°C liegt und die Reaktionsdauer 2 bis 5 Stunden beträgt.
4. Verfahren nach Anspruch 3, worin die Reaktionstemperatur 40 bis 70°C beträgt und die Reaktionsdauer 2 bis 3 Stunden beträgt.
5. Verfahren nach Anspruch 2, 3 oder 4, worin das durch die Formel (II) dargestellte t-Butyl(S)-(-)-4-halogen-3-hydroxybutyrat in einem aprotischen, polaren Lösungsmittel vor der Reaktion mit dem Cyanid gelöst wird.
6. Verfahren nach Anspruch 5, worin das aprotische, polare Lösungsmittel Dimethylformamid, Acetonitril oder Dimethylsulfoxid ist.
7. Verfahren nach einem der Ansprüche 2 bis 6, worin das Cyanid in der Form einer wäßrigen Lösung vorhanden ist.

Revendications

1. (R)-(-)-4-cyano-3-hydroxybutyrate de t-butyle représenté par la formule (I) :

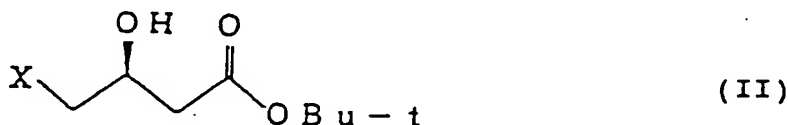


10 dans laquelle Bu-t représente un groupement t-butyle.

2. Procédé de préparation de (R)-(-)-4-cyano-3-hydroxybutyrate de t-butyle représenté par la formule (I) :



25 dans laquelle Bu-t représente un groupement t-butyle, comprenant la réaction d'un (S)-(-)-4-halogéno-3-hydroxybutyrate de t-butyle représenté par la formule (II) :



35 dans laquelle Bu-t est tel que défini ci-dessus et X représente un atome de chlore ou un atome de brome, avec du cyanure de sodium ou du cyanure de potassium.

- 40
3. Procédé selon la revendication 2, dans lequel la température de réaction est comprise dans la gamme de 15 à 100°C et la durée de réaction est comprise entre 2 et 5 h.
4. Procédé selon la revendication 3, dans lequel la température de réaction est comprise entre 40 et 70°C et la durée de réaction est comprise entre 2 et 3 h.
- 45
5. Procédé selon la revendication 2, 3 ou 4, dans lequel on dissout le (S)-(-)-4-halogéno-3-hydroxybutyrate de t-butyle représenté par la formule (II) dans un solvant polaire aprotique avant la réaction avec le cyanure.
6. Procédé selon la revendication 5, dans lequel le solvant polaire aprotique est le diméthylformamide, l'acétonitrile ou le diméthylsulfoxyde.
7. Procédé selon l'une quelconque des revendications 2 à 6, dans lequel le cyanure est présent sous la forme d'une solution aqueuse.
- 50